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Microhabitat selection and communal nesting in the insular Psychedelic Rock Gecko, *Cnemaspis psychedelica*, in Southern Vietnam with updated information on trade

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Abstract

The Psychedelic Rock Gecko, *Cnemaspis psychedelica*, was described in 2010 and certainly belongs to the most spectacular gecko discoveries worldwide. The species is endemic to two small offshore islands in Rach Gia Bay. Its striking colour pattern makes the species highly attractive for the international pet market. The existent *Cnemaspis* population is negatively affected by habitat degradation and predation by introduced macaques. We herein provide the first characterisation of microhabitat selection of this species, including seasonal variation on Hon Khoai and Hon Tuong islands, Ca Mau Province, Vietnam. We found that characteristics of the selected microhabitat, such as substrate type, temperature and canopy cover slightly differed between the wet and dry seasons. We also demonstrated age-related differences in the selection of perch heights. Communal nesting was, for the first time, reported for *C. psychedelica*, as well as natural predation by a snake species (*Lycodon capucinus*). In addition, we documented ongoing habitat destruc-

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tion on Hon Khoai Island and recorded illegal trade of live Psychedelic Rock Geckos for the first time on local pet markets in both northern and southern Vietnam. Our findings highlight the need for improved conservation measures in order to reduce anthropogenic impacts on wild populations of *C. psychedelica*.

Keywords
Microhabitat requirements, seasonal variation, communal nesting, natural predators, illegal trade, conservation

Introduction

The old world gecko genus *Cnemaspis* Strauch is considered as one of the most species-rich paleotropical gekkonid genera, encompassing more than 100 species with a widespread distribution throughout tropical Africa, South Asia and Southeast Asia (Smith 1935, Wickramasinghe and Munindradasa 2007, Ganesh et al. 2011, Uetz and Hošek 2017, Vidanapathirana et al. 2014, Srinivasulu et al. 2015). To date, six species of *Cnemaspis* have been recorded from Vietnam, namely *C. aurantiacopes*, *C. boulengeri*, *C. caudanivea*, *C. nuicamensis*, *C. tucdupensis* and *C. psychedelica*. Two of these from Vietnam are endemic to islands (Grismer and Ngo 2007, Grismer et al. 2010). One of them is the insular Psychedelic Rock Gecko, *Cnemaspis psychedelica*, which was only described from isolated Hon Khoai Island, Ca Mau Province, Southern Vietnam in 2010 (Grismer et al. 2010). More recently *C. psychedelica* was also recorded on a further offshore island, namely Hon Tuong isle, which only covers a small area of ca. 300 m^2 (Ngo et al. 2016). Still, the species is assumed to be endemic to islands of Rach Gia Bay, southern Vietnam.

The known wild population of the species was estimated to comprise approximately 500 mature individuals (Ngo et al. 2016). Although the wild population of *C. psychedelica* appears to be relatively stable and actively reproducing, it is currently suffering from increasing habitat degradation on the small Hon Khoai Island (Ngo et al. 2016). Particularly, those granite formations, which represent essential microhabitat sites for *C. psychedelica* are frequently blasted by dynamite in order to flatten several areas on the island for construction of roads or artificial ponds (Ngo et al. 2016). Additionally, poaching for the international pet trade has already been recorded shortly after description of the species. *C. psychedelica* has been observed in European reptile fairs and on the online markets for prices of up to 3,000 EUR/pair (Auliya et al. 2016, Ngo et al. 2016). In addition, the introduction of invasive Long-tailed Macaques (*Macaca fascicularis*) on Hon Khoai Island poses another potential threat to *C. psychedelica,* as macaques were observed to feed on geckos and theirs eggs (Grismer et al. 2010, Ngo et al. 2016). The extremely restricted habitats, together with a low reproduction rate, make the species especially vulnerable to external stressors and limit its capacity to recover from threats such as harvesting. As a result, the protection needs of *C. psychedelica* have received attention from all around the world. Based on a first population and risk assessment, the species has recently been classified as "Endangered" on the IUCN Red List of Threatened species (Nguyen et al. 2016) and was subsequently listed in Appendix I of the Convention

on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2016). Furthermore, immediate conservation measures have been initiated including the establishment of an in-country *ex situ* assurance population for *C. psychedelica* (Ziegler et al. 2016). However, detailed information about microhabitat requirements of the species, which are essential for both adequate habitat protection measures and to successfully implement conservation breeding programmes, are still lacking.

The study provides detailed data on microhabitat selection of *C. psychedelica* within its natural habitat. We examined differences in microhabitat selections of lizards between the wet and dry seasons, as well as variations in habitat use amongst age classes. Furthermore, we provide new information about egg deposition behaviour, natural predation and ongoing habitat destruction on Hon Khoai Island, as well as new evidence for local trade in *Cnemaspis psychedelica*, highlighting the need for immediate measures to protect the remaining populations.

Methods

Field surveys

Study sites were selected based on known occurrences of *C. psychedelica* on Hon Khoai and on Hon Tuong islands, Ca Mau Province, southern Vietnam, according to previous surveys (Grismer et al. 2010, Ziegler et al. 2016). The region is characterised by a monsoon sub-equatorial climate with constant annual temperatures, but with distinct climatic difference between a dry and a wet period with heavy rains (Fig. 1) (General Statistics Office of Vietnam 2016).

Field surveys were carried out during the wet season in November 2015 as well as during the beginning of the dry season in January 2016. Another short survey on Hon Khoai Island took place in January 2017. We mainly conducted night excursions after sunset between 19:00 h and 24:00 h. In order to determine the sex of the geckos and for taking measurements, individuals were captured by hand and subsequently released at the same spot in the morning or afternoon of the next day between 10:00 h and 17:00 h. While releasing geckos, further sighted individuals were also recorded, measured and released. Each gecko was measured with a digital slide-caliper to the nearest 0.1 mm. Abbreviations are as follows: snout-vent length (SVL), measured from tip of snout to anterior margin of cloaca; tail length (TL), measured from posterior of cloaca to tip of tail in geckos (Grismer et al. 2010).

In order to investigate the biodiversity of Hon Khoai Island, we carried out respective field surveys in January 2016. During these surveys, a few amphibians and reptiles were also collected and subsequently deposited in the collection of the Institute of Ecology and Biological Resource (IEBR), Hanoi, Vietnam. Stomach contents of collected snakes were analysed after dissection in order to identify whether they might represent natural predators of *C. psychedelica*.

Year	Months	Temp. (°C)	Prec. (mm)
2015	11	28	272.4
	12	27.8	48.6
2016	1	27.9	0.2
	2	27.3	2.1
	3	28	0
	4	30.1	4
	5	29.9	161.4
	6	28.3	230.8
	7	28.3	432.2
	8	28.4	271.9
	9	27.6	345
	10	27	501.1
	11	27.9	183.6
	12	27.1	171.8

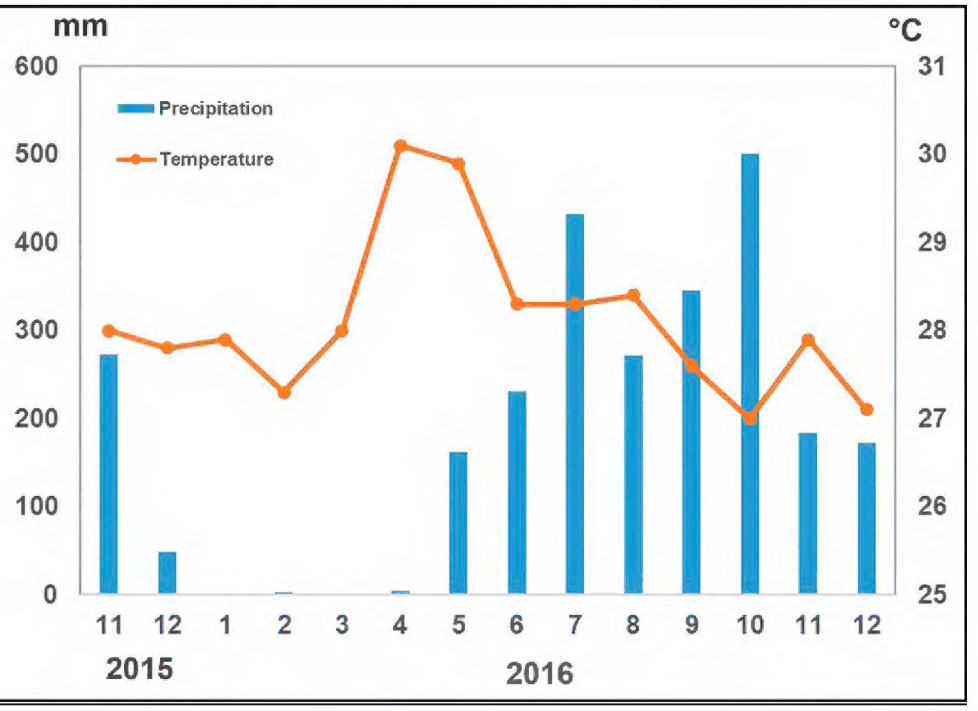

Figure 1. Mean annual air temperatures (°C) and monthly precipitation (mm) in 2015 and 2016 in Ca Mau Province, Vietnam (source: https://www.gso.gov.vn/default.aspx?tabid=713, accessed on 05 July 2018).

Microhabitat assessment

Microhabitat parameters were recorded for each sighted individual, including substrate type (classified as cliff, rock, branch, leaves, forest floor), perch height [in m] (vertical distance between captured animal and ground), percentage of vegetation or rock coverage above animal, position (resting outside, under a rock or within a crevice), substrate surface condition (dry or wet), activity (resting, feeding, foraging), air temperature [°C], substrate temperature [°C], animal's body surface temperature [°C] and relative air humidity [%]. Air temperature and relative air humidity were measured with a digital thermo-hygrometer at a vertical height from the ground up to 2m height at each microsite (TFA Dostmann/Wertheim Kat.Nr.30.5015), while substrate and body surface temperatures of animals were determined with an infrared thermometer (Measupro IRT20).

To identify intraspecific differences in microhabitat selection of *C. psychedelica*, individuals were classified into different age classes according to Ngo et al. (2016) based on snout-vent lengths (SVL): SVL < 58 mm = juvenile and SVL ≥ 58 mm = adult.

Chi-square tests and t-tests with $P \leq 0.05$ were performed to determine significant differences in selected microhabitat parameters with categorical and continuous variables, respectively, between wet and dry season and amongst age classes. Statistical analyses were applied with the programme SPSS Version 16.0 (SPSS Inc., Chicago).

Threat assessment

To obtain an overview on the availability of and evidence for trade in *Cnemaspis psychedelica* in Vietnam, we visited several local pet markets (one in Ca Mau Province where the species occurs, one in Dong Nai Province, one in Ho Chi Minh City and one in Ha Noi City) and further investigated different internet platforms, reptile Facebook pages and

Forums. We also interviewed three local dealers offering the lizard online and two local keepers in March 2018, in order to obtain information on origins, commercial prices and networks of illegal trade in this species. Additionally, we conducted field surveys at previous survey sites located on Hon Khoai Island, Ca Mau Province in January 2017 to evaluate anthropogenic threats. Nearly 10 road workers on Hon Khoai Island were interviewed to determine the local use of the species. Names of interviewees were kept anonymous to ensure data privacy rights and internet links were not disclosed to prevent misuse.

Results

Microhabitat characterisation

A total of 569 sightings took place (156 during the wet season and 413 during the dry season) including both subpopulations from Hon Khoai and Hon Tuong islands, respectively. *Cnemaspis psychedelica* was found to be active in the surroundings of granite basements within thick forest coverage, dominated by semi-deciduous forest vegetation. Mean air temperatures were with 29.1 ± 0.75 °C (26.0–31.5 °C, n = 569) slightly higher than average substrate temperatures of 26.6 ± 1.07 °C (20.0–31.7 °C, n = 567). Regarding seasons, substrate temperatures were with 26.9 ± 0.77 °C (25.2–31.7 °C, n = 411) slightly higher during the dry season than temperatures during the wet season (26.1 ± 1.48 °C, 20.0–29.6 °C, n = 156) (t-Test, t = 6.23, df = 187.8, P < 0.001) (see Fig. 2C, Table 1). Generally, temperatures remained relatively constant throughout the year without high fluctuations (Fig. 1). In contrast, relative humidity at microsites was with 86.2 ± 6.1% (71–100%, n = 156), distinctly higher during the wet season compared to 73.3 ± 2.56% (65–80%, n = 413) during the dry season (t-Test, t = 25.4, df = 175.9, P < 0.001) (see Table 1).

Table 1. Environmental parameters characterising the microhabitat of *Cnemaspis psychedelica*.

Parameters	Wet season (Nov)	Dry season (Jan)	T-test
Canopy cover [%]	0–100 (79.6±30.5) (n=156)	0–100 (91.2±20.1) (n=413)	F=2.3; P=0.0004<0.05
Height [m]	0.01–3 (0.75 ±0.39) (n=156)	0.01–2.8 (0.7±0.33) (n=413)	F= 1.17; P-value= 0.22>0.05.
Elevation [m]	1–81 (32.0±19.9) (n=158)	3–79 (35.6±17.8) (n=407)	
Ambient Temp. [°C]	26–31.5 (28.5±0.9) (n=158)	23.8–30.3 (29.3±0.4) (n=413)	
Substrate Temp. [°C]	20–29.6 (26.1±1.5) (n=156)	25.2–31.7 (26.9±0.8) (n=411)	F=2.6; P-value=0.0001<0.05
Relative air Humidity [%]	71–100 (86.2±6.2) (n=158)	65–80 (73.3±2.6) (n=413)	
Monthly Precipitation (mm) (GSOV. 2016) (access 05 July 2018)	272.4	0.2	
Mean monthly Temp. [°C] (GSOV. 2016) (access 05 July 2018)	28.0	27.9	

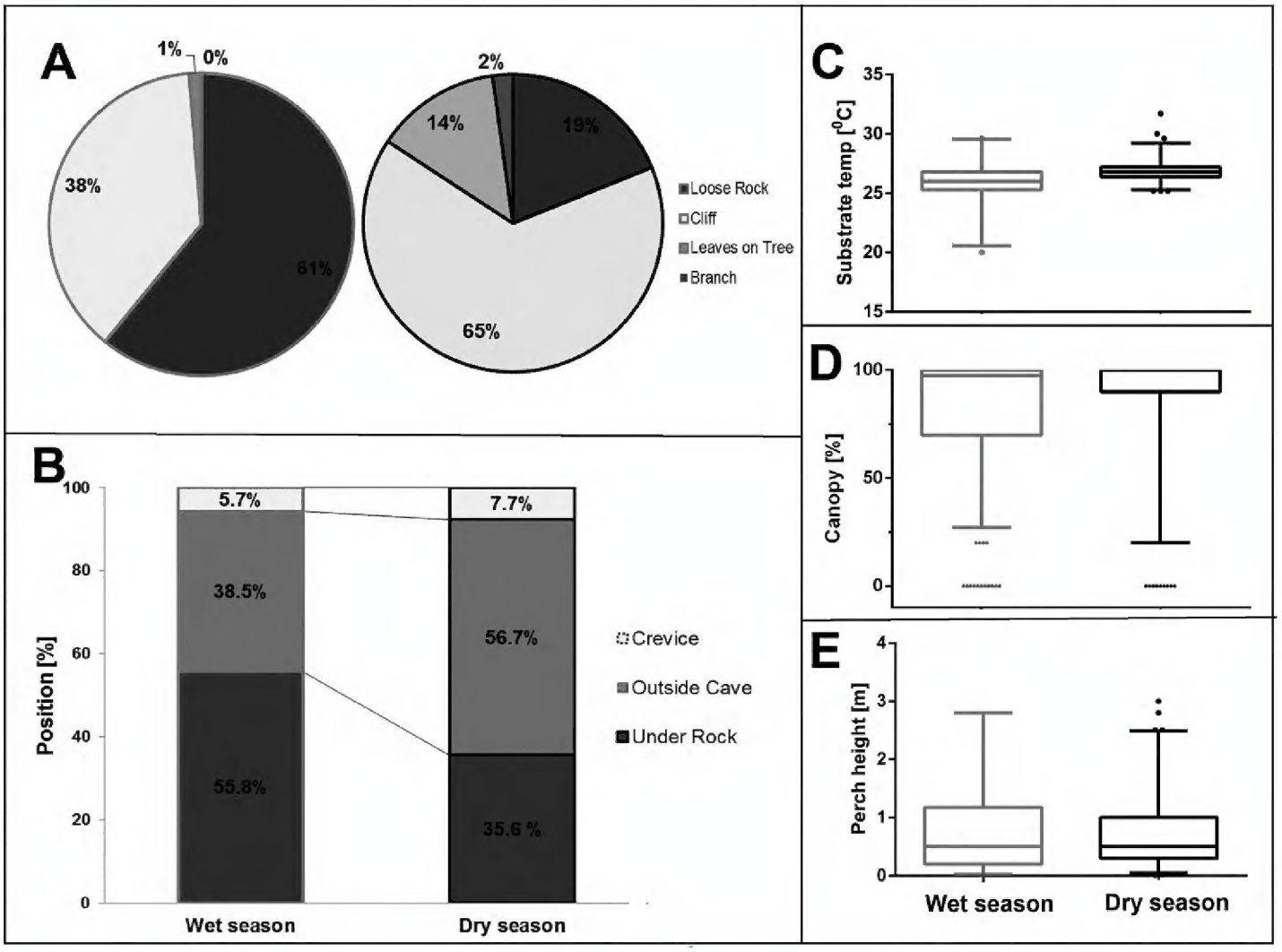

Figure 2. Microhabitat selection of *Cnemaspis psychedelica* **A** Substrate selection **B** Microsite selection **C** Box plots of substrate temperature **D** Box plots of canopy coverage **E** Box plots of perch height.

Microhabitat use

The Psychedelic Rock Gecko was found active during both the wet and dry seasons. Regarding daily activity pattern, *C. psychedelica* was observed active during any sighting between 10:00 h to 24:00 h. The vast majority of lizards were found in the shade, even if a patch of direct sunlight was in close proximity.

During the wet season, *C. psychedelica* was mainly found on loose granite rocks, followed by cliff and leaves on trees (61%, 38%, 1%, n = 413, respectively, see Fig. 2A), but never on branches or on the forest floor. During the dry season, the main selected substrate types were cliffs, followed by loose granite rocks, leaves on trees and branches (65%, 19%, 14%, 2%, n = 156, respectively, Chi^2 = 36.4, df = 3; $P < 0.001$, see Fig. 3A–D). We mainly encountered lizards resting under rock formations during the wet season, while animals frequently resided outside of caves or rock shelters during the dry season (outside of caves: 38.5% during the wet season vs. 56.7% during the dry season, respectively, see Fig. 2B, Chi^2 = 19.1, df = 2, $P < 0.001$). We further observed *C. psychedelica* at mean heights of 0.71 ± 0.6 m (0.01–3 m, n = 569) (see Table 1). There was no difference in the height selections of lizards between wet and dry season (t-Test, t = 0.86, df = 567, $P > 0.05$) (see Fig. 2E). While animals tended to reside under a mean canopy coverage of 79.6 ± 30.5% (n = 156) during the wet season, a higher percentage

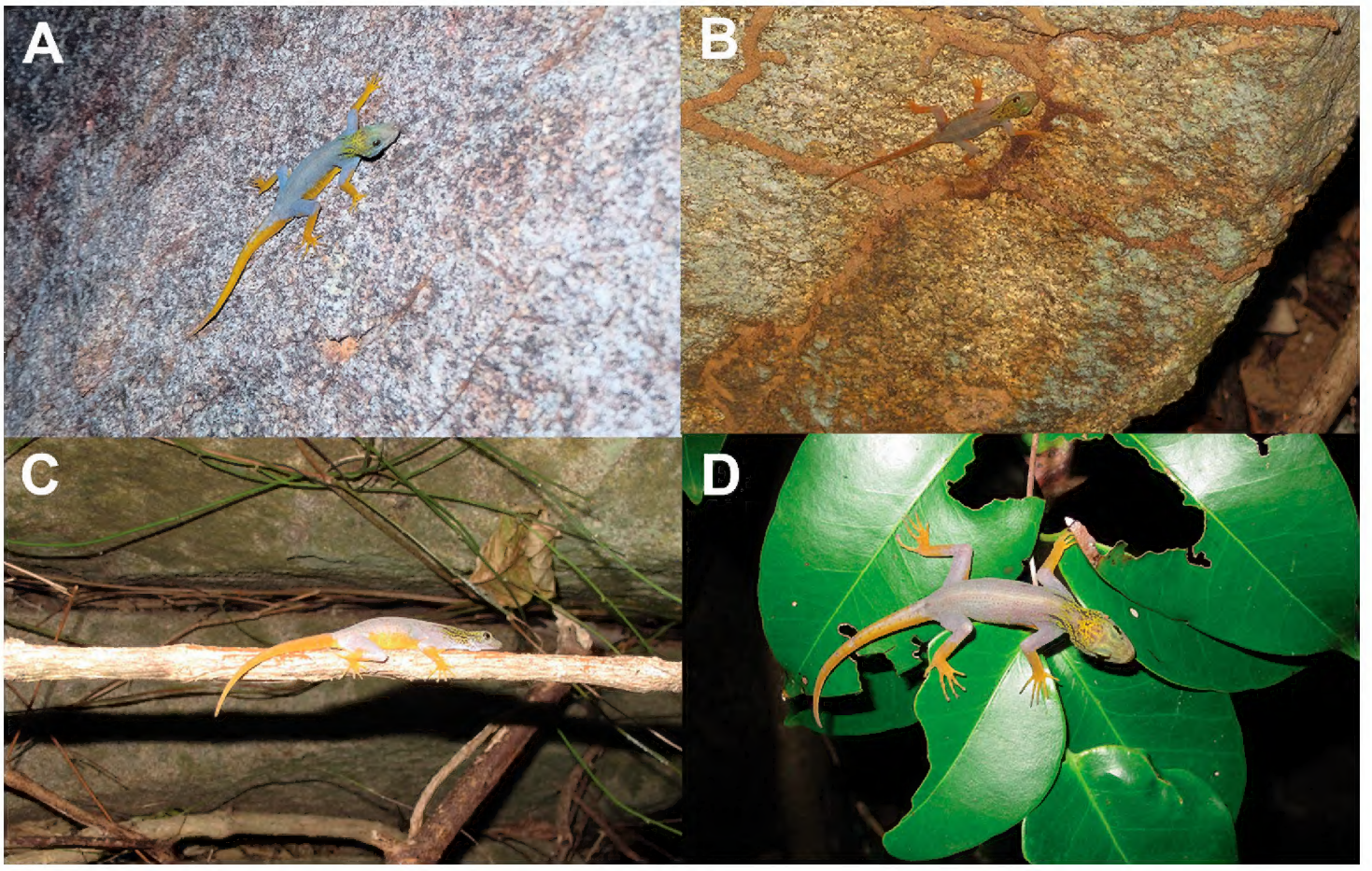

Figure 3. A–D Selected substrates of *Cnemaspis psychedelica* on Hon Khoai Island.

of canopy cover of 91.2 ± 20.1% (n = 413) above the animals was recorded during the dry season (t-Test, t = 4.4, df = 208, P < 0.001) (see Fig. 2D, Table 1). We observed that the majority (about 75.9%, n = 432) of lizards were resting during surveys, whereas only about one quarter of individuals (n = 137) were found actively foraging.

We found adult specimens at mean heights of 0.76 m (n = 419), while juveniles commonly resided at lower heights of 0.61 m (n = 149) (t = 2.9, df = 296.4, P = 0.004). Both age classes preferred to occupy granite rock formations (60.8%, 74.2%, respectively), while another high percentage of adults resided on cliffs (29% vs. 9%, respectively) and a lower percentage of adults occupied branches (7.8%, 16.8%, respectively).

Oviposition

Egg depositions of *Cnemaspis psychedelica* happened on flat surfaces of cliff walls, without direct sunlight. Egg deposition sites were located under high vegetation coverage during both seasons (see Fig. 4A). We did not find any eggs attached to branches or leaves. Newly laid eggs were bright and clear white in colouration, then changed to pinkish (early development of embryos) and then to a slightly grey colour (with developed embryos). Eggs were almost round in shape, except for the flattened side attached to the substrate. Clutches of *C. psychedelica* consistently comprised two eggs. Clutches of different individuals of *C. psychedelica* were commonly deposited in close proximity to each other, forming clusters. Furthermore, new clutches were frequently found to be deposited on top of remains of eggshells from previous clutches. We measured the min-

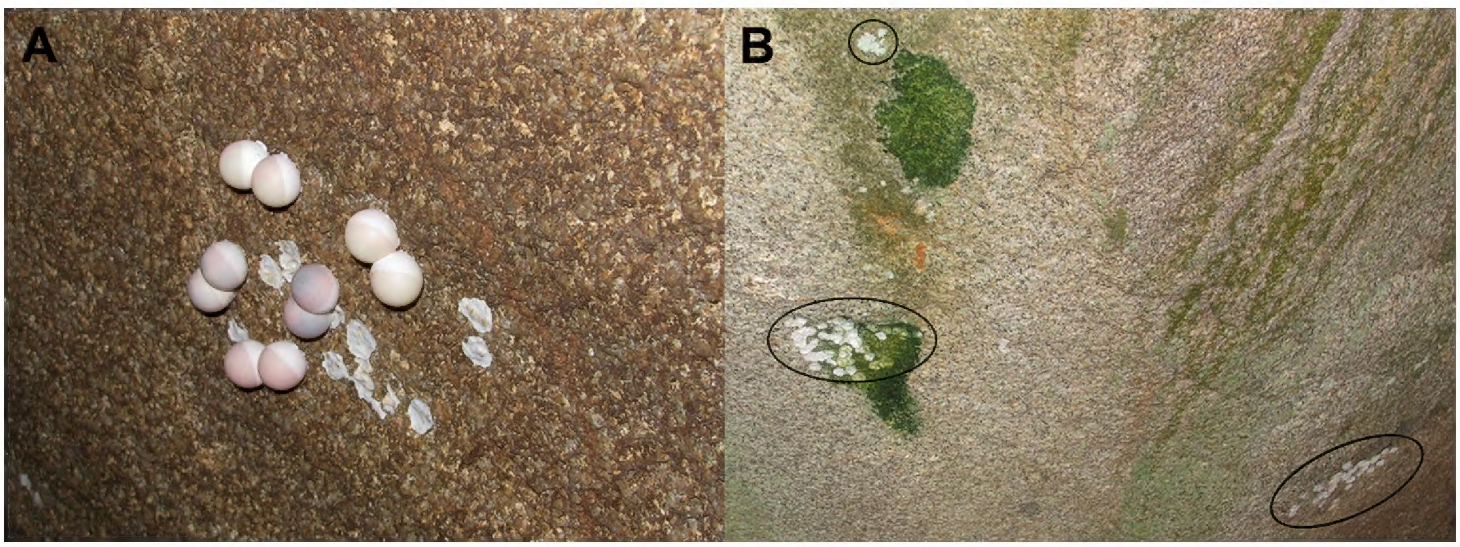

Figure 4. A Communal nesting in *Cnemaspis psychedelica* **B** Clumped distribution of clutches.

imum distance amongst different clusters as about 25 cm. Furthermore, the maximum observed number of unhatched eggs within a cluster was 10 eggs/5 pairs (see Fig. 4A, B). The clusters were generally deposited at heights ranging from 0.3 to 3.5 m above the ground. We frequently found several adult individuals in close proximity to the aggregation of clusters. Solitary clusters comprising only two eggs were usually observed higher than 2.5 m above the ground and were scarcely attended by adult individuals.

Natural predation

An ingested adult female of *C. psychedelica* (IEBR. 4141: SVL = 68.64 mm, TL = 74.8 mm) has been found within a preserved and subsequently dissected Common Wolf Snake (*Lycodon capucinus*, IEBR. 4211: SVL = 471.4 mm, TL = 95.11 mm) (Fig. 5A). The gecko was ingested with the head first and accounted for 30.4% of the snake's SVL.

Threats

During the survey in January 2017, the optimal habitats of *C. psychedelica* on Hon Khoai Island were found to have experienced further degradation due to expanding road construction and the building of further artificial ponds (see Fig. 6A, B). In particular, destruction with dynamite has entirely removed the natural habitat of *C. psychedelica* at one survey site and further extended to other survey areas.

Trade in living *C. psychedelica* has been recorded by our team in local pet shops from northern Vietnam (Ha Noi City) and southern Vietnam (namely, Ca Mau Province where the species is distributed, further in Dong Nai Province and Ho Chi Minh City), as well as online in Vietnamese Reptile Forums, Zalo Online and Facebook. During our visit to two pet shops, one in Ca Mau Province and one in Dong Nai Province in March 2018, we observed 20 and only one remaining *C. psychedelica*,

Figure 5. A Adult female Psychedelic Rock Gecko found as a prey item in the stomach of a Common Wolf Snake (*Lycodon capucinus*) **B** Wild-caught individual of *Cnemaspis psychedelica* offered for sale in a pet shop in Dong Nai Province, Southern Vietnam **C, D** Preserved reptile species in alcohol, used for traditional medicine on Hon Khoai Island.

respectively, which were kept in small boxes (Fig. 5B). A large number of animals had already been previously exported. Local dealers confirmed that *C. psychedelica* have been caught from the wild for sale since 2015. According to interviews with local dealers, 15 to 70 specimens from Vietnam have been frequently offered for sale and export to Thailand and Indonesia (for USD 100–300 per individual) and afterwards smuggled to Russia and Europe for USD 700 per individual, while prices achieved in the local trade were comparably lower (USD 20–40 per animal). According to one private keeper in Ho Chi Minh City, *C. psychedelica* have been offered for USD 450 per pair from another local pet shop in Ho Chi Minh City since 2016. In March 2018, he had 15 breeding specimens for sale for USD 200 per individual and several eggshells were observed in his terrarium. Regarding international trade, at least 23 specimens

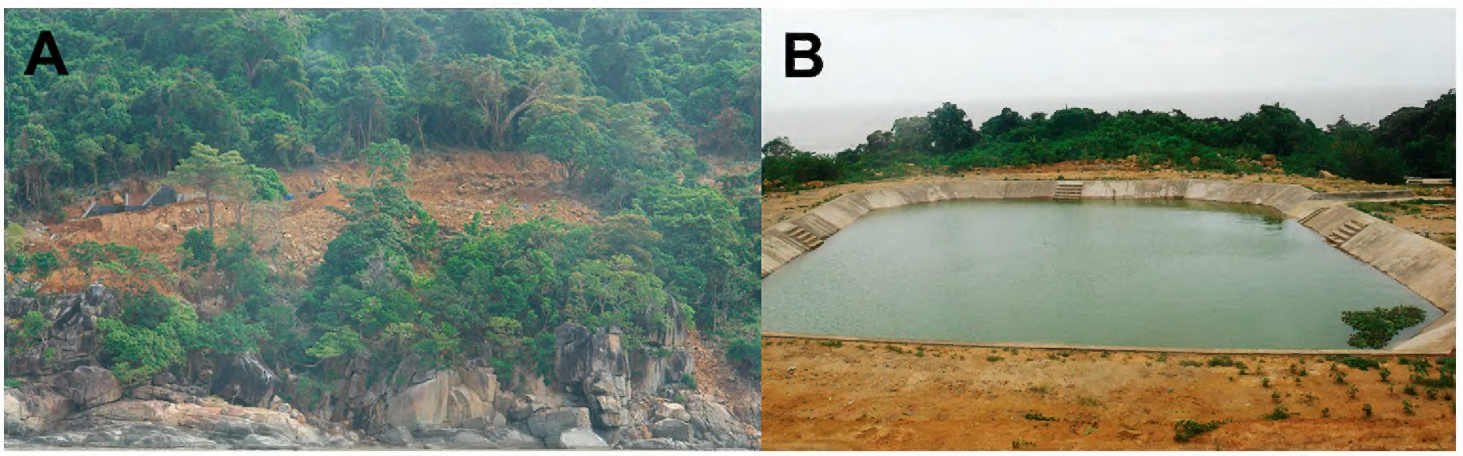

Figure 6. A Forest degradation caused by building new roads **B** New artificial pond on Hon Khoai Island.

of *C. psychedelica* were found being offered for sale online (such as on Facebook) in Europe between September 2017 and March 2018 (Altherr et al. pers. comm.).

During the survey in January 2017, we found some reptile species such as *Cnemaspis psychedelica, Cyrtodactylus leegrismeri, Draco maculatus, Hemidactylus frenatus, Gehyra mutilata, Gekko gecko* and *Ahaetulla prasina* soaked together in rice wine and used for traditional medicine by road workers on Hon Khoai Island (Figs. 5C and D). According to interviews with road workers, *C. psychedelica* individuals have been kept as pets in their terrariums at home since 2015.

Discussion

Microhabitat

We found that selected microhabitat characteristics such as substrate type, temperature and canopy cover slightly differed between the wet and dry seasons. Our data showed that the species is more frequently found under granite rock formations during the wet season, probably to avoid heavy rains (10 of 11 survey days). During the dry season, geckos were observed in remarkable numbers outside of caves or rock formations. The species was found strongly associated with granitic rock formations and cliffs during all life stages. While *C. psychedelica* has never been found on the forest floor and only scarcely within the vegetation, clutches were also unexceptionally deposited on rock formations at heights of at least 0.3 m above the ground. We assume that vertical cliffs might provide shelter from ground-dwelling predators.

Furthermore, animals were found at spots which were more densely covered with canopy during the dry season than during the wet season, which could be their behaviour to avoid direct sun exposure. Accordingly, fewer animals were found along transects with only slight vegetation coverage during the wet than during the dry season. These findings suggest the dependence of *C. psychedelica* on the availability of shaded habitats. Egg depositions were also exclusively found on cliffs, which are facing away from the sun.

Our study revealed that the body surface temperature of *C. psychedelica* was positively correlated with the substrate temperature ($r_s = 0.51$, $P < 0.001$, $n = 567$). Thus,

as in other ectotherms, basic physiological functions of *C. psychedelica*, such as locomotion, growth and reproduction are determined by the environmental temperature. Since tropical lizards are considered to have narrow temperature optima and only few options for behavioural and physiological compensation, they are assumed to be, in particular, vulnerable to extinction by climate warming (Deutsch et al. 2008; Doody and Moore 2010; Huey et al. 2009; Vié et al. 2009).

Communal nesting and spatial distribution

We frequently observed aggregated oviposition sites and the placement of fresh eggs on top of or close to previous oviposition sites. Communal nesting is defined as "non-incidental deposition of eggs at a shared nest cavity by two or more co-specifics" (Espinoza and Lobo 1996). Such communal oviposition has been described in numerous lizard species including other *Cnemaspis* species (e.g. Kalaimani 2015; Lima et al. 2011; Magnusson and Lima 1984; Vitt 1986; Soares de Oliveira et al. 2015; Somaweera 2009; Srinivasulu and Srinivasulu 2013a, b; Werner 2002) and is assumed to offer potential benefits such as protection, predator-satiation and metabolic heating (Gurgel de Sousa and Freire 2010, Sönmez 2018). Mateo and Cuadrado (2012) experimentally proved that hatching success was significantly higher in communal than in solitary clutches of the gecko *Ptyodactylus oudrii* and significantly decreased when adult lizards were excluded from the oviposition site. Accordingly, we also observed high densities of *C. psychedelica* specimens of different ages and sexes, accumulated in close vicinity to communal oviposition sites following the principle of clumped distribution. The maximum observed density was 23 individuals, including 18 adults (9 males), per 4 m^2. The clumped presence of individuals, independent of age and sex in close proximity to clutches, has also been observed by Mateo and Cuadrado (2012), assuming a high population density and restricted availability of suitable oviposition sites to trigger communal nesting.

With a closer look on the spatial distribution of *C. psychedelica*, we found age related differences in perch heights, namely juveniles occurring at significantly lower heights than adults. Similar habitat divergences between juveniles and adult individuals have also been reported for Cat Ba Tiger Geckos and Crocodile Lizards in Vietnam (Ngo et al. in press, van Schingen et al. 2015) and gekkonids from New Caledonia (Snyder et al. 2010). Van Schingen et al. (2015) suggested that climbing might be a trade-off in lizards between saving energy costs and the reduction of interactions with competitors and predators. However, this hypothesis needs to be tested in future studies. Furthermore, adult specimens were usually found at similar heights to the closest communal clusters, which might indicate some kind of parental care behaviour.

Predation

Reptiles, including lizards are commonly prey of other vertebrates, such as mammals and reptiles (Whiles and Grubaugh 1993). The first case of a snake as a predator of

Cnemaspis psychedelica, as herein reported, is thus nothing extraordinary (e.g. Herman 2017, Nogueira et al. 2013, Vrcibradic and Eisfeld 2016, Whitaker and Captain 2004). However, Long-tailed Macaques (*Macaca fascicularis*) as predators, as reported by Grismer et al. (2010), is a worrying fact, as this species was introduced and thus does not belong to the normal ecosystem of Hon Khoai Island. The artificially enhanced predation probably impacts the population dynamics of *C. psychedelica*.

Anthropogenic threats and implications for conservation

Lizards with limited geographic distributions, such as *Cnemaspis psychedelica,* may be extremely vulnerable to local habitat loss or alteration (Sodhi and Ehrlich 2010). The limited availability of habitats for the species, namely only two offshore islands in the Rach Gia Bay, Vietnam, makes the species particularly vulnerable to habitat destruction. The optimal microhabitats of *C. psychedelica* on Hon Khoai Island were found to have experienced ongoing degradation due to expanding infrastructure. If the present trend continues, not only *C. psychedelica*, but also other species and yet undescribed or just recently discovered diversity on the island (Nguyen et al. 2018), will become potentially threatened by extinction. Furthermore, these constructions will probably further facilitate hunters to illegally approach Hon Khoai Island. *C. psychedelica* has already been observed on international markets, but detailed information about illegal traffic networks has been lacking (Altherr 2014; Auliya et al. 2016, Ngo et al. 2016). New evidence from interviews with local reptile dealers indicates that they paid local fishermen and visited Hon Khoai Island as tourists to collect live specimens of *C. psychedelica* without any permits. Live specimens of *C. psychedelica* have been frequently offered for sale in southern and northern Vietnam and are mainly smuggled to Thailand as a middle country and then exported to be sold in Russia and Europe for relatively high prices. However, the number of smuggled animals has allegedly declined to fewer than a total of 20 individuals per deal which might be an effect of the improved control of trade in the species due to the recent inclusion in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as well as promulgating strict decrees that have restricted harvest and reduced the stress from over-exploiting of a number of lizard species (Sodhi and Ehrlich 2010). However, traders still continue to harvest wild individuals and the species is still found to be offered in local and European markets probably due to high demands and commercial value. Our findings indicate that there are currently no legal commercial harvests and trade in the species in Vietnam, implying that wild specimens entering the international trade have been illegally harvested. We highly recommend that the Vietnamese authorities more strictly control the illegal collection of *C. psychedelica* in the natural habitat. Furthermore, wildlife law enforcement along key border regions should be highly improved to alleviate the illegal exploitation and trade, not only in wild *C. psychedelica*, but also in other taxa.

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References

Altherr S (2014) Stolen Wildlife – Why the EU needs to tackle smuggling of nationally protected species. Report by Pro Wildlife, Munich, 1–29.

Auliya M, Altherr S, Ariano-Sanchez D, Baard EH, Brown C, Cantu J-C, Gentile G, Gildenhuys P, Henningheim E, Hintzmann J, Kanari K, Krvavac M, Lettink M, Lippert J, Luiselli L, Nilson G, Nguyen TQ, Nijman V, Parham J, Pasachnik SA, Pedrono M, Rauhaus A, Rueda D, Sachnez M-E, Schepp U, van Schingen M, Scheeweiss N, Segniagbeto GH, Shepherd C, Stoner S, Somaweera R, Sy E, Türkosan O, Vinke S, Vinke T, Vya R, Williamson S, Ziegler T (2016) Trade in live reptiles, its impact on wild populations, and the role of the European market. Biological Conservation 204: 103–119. http://dx.doi.org/10.1016/j.biocon.2016.05.017

CITES (2016) Seventeenth Meeting of the Conference of the Parties, 24 September–5 October 2016, South Africa, 2016, Proposal 33. https://cites.org/sites/default/files/eng/cop/17/prop/060216/E-CoP17-Prop-33.pdf

Deutsch CA, Tewksbury JJ, Huey RB, Sheldon KS, Ghalambor CK, Haak DC, Martin PR (2008) Impacts of climate warming on terrestrial ectotherms across latitude. Proceedings of the National Academy of Sciences of the United States of America 105(18): 6668–6672. https://doi.org/10.1073/pnas.0709472105

Doody JS, Moore JA (2010) Conceptual model for thermal limits on the distribution of reptiles. Herpetological Conservation and Biology 5: 283–289.

Espinoza RE, Lobo F (1996) Possible communal nesting in two species of Liolaemus lizards (Iguania: Tropiduridae) from northern Argentina. Herpetological Natural History 4: 65–68.

Ganesh SR, Sreekar R, Pal SP, Ramchandra G, Srinivasulu C, Srinivasulu B (2011) Discovery and first description of male Cnemaspis heteropholis Bauer, 2002 (Reptilia: Gekkonidae) from Agumbe, central Western Ghats, India. Journal of Threatened Taxa 3(8): 2023–2027. https://doi.org/10.11609/JoTT.o2614.2023-7

General Statistics Office of Vietnam (2016) The Climatic Database. https://www.gso.gov.vn/default.aspx?tabid=713 [accessed 05 July 2018]

Grismer LL, Ngo VT (2007) Four new species of the gekkonid genus *Cnemaspis* Strauch 1887 (Reptilia: Squamata) from Southern Vietnam. Herpetologica 63(4): 482–500. https://doi.org/10.1655/0018-0831(2007)63[482:FNSOTG]2.0.CO;2

Grismer LL, Ngo VT, Grismer JL (2010) A new colorful new species of insular rock gecko (*Cnemaspis* Strauch 1887) from southern Vietnam. Zootaxa 2352: 46–58.

Gurgel de Sousa PA, Freire EMX (2010) Communal nests of Hemidactylus mabouia (Moreau de Jonnès,1818) (Squamata: Gekkonidae) in a remnant of Atlantic Forest in northeastern Brazil. Biotemas 23(3): 231–234.

Herman JE (2017) *Leptophis ahaetulla* (Parrot Snake). Diet and Mortality. Herpetological Review 48(2): 452.

Huey RB, Deutsch CA, Tewksbury JJ, Vitt LJ, Hertz PE, Alvarez Perez HJ, Garland Jr T (2009) Why tropical forest lizards are vulnerable to climate warming. Proceedings of the Royal Society B 276: 1939–1948.

Kalaimani A (2015) Notes on egg laying sites of Calodactylodes aureus (Beddome, 1870) in Tirupattur Forest Division, Southern India. Herpetological Bulletin 131: 24–25.

Lima DC, Passons DC, Borges-Nojosa (2011) Communal nests of *Phyllopezus periosus*, an endemic gecko of the Caatinga of northeastern Brazil. Salamandra (Frankfurt) 47(4): 227–228.

Magnusson W, Lima A (1984) Perennial communal nesting by Kentropyx calcaratus. Journal of Herpetology 18(1): 73–75. https://doi.org/10.2307/1563673

Mateo JA, Cuadrado M (2012) Communal nesting and parental care in Oudris Fan-Footed Gecko (*Ptyodactylus oudrii*): Field and experimental evidence of an Adaptive Behavior. Journal of Herpetology 46(2): 209–212. https://doi.org/10.1670/10-072

Ngo HN, Le QT, Nguyen QT, Le DM, van Schingen M, Ziegler T (in press) First record of the Cat Ba tiger gecko, *Goniurosaurus catbaensis*, from Ha Long Bay, Quang Ninh Province, Vietnam: Microhabitat selection, potential distribution, and threat evaluation. Amphibian & Reptile Conservation.

Ngo HN, Nguyen TQ, Nguyen TV, Barsch F, Ziegler T, van Schingen M (2016) First population assessment of the endemic insular Psychedelic Rock Gecko (*Cnemaspis psychedelica*) in southern Vietnam with implications for conservation. Amphibian & Reptile Conservation 10(2): 18–26.

Nguyen ST, Oshida T, Dank PD, Bui HT, Motokawa M (2018) A new species of squirrel (Sciuridae: *Callosciurus*) from an isolated island off the Indochina Peninsula in southern Vietnam. Journal of Mammalogy 99(4): 813–825. https://doi.org/10.1093/jmammal/gyy061

Nguyen TQ, Ngo HN, Ziegler T, van Schingen M (2016) *Cnemaspis psychedelica*. The IUCN Red List of Threatened Species 2016: e. T97210381A97210384.

Nogueira CHO, Figueiredo-de-Andrade CA, Freitas NN (2013) Death of a juvenile snake Oxyrhopus petolarius (Linnaeus, 1758) after eating an adult house gecko Hemidactylus mabouia (Moreau de Jonnès, 1818). Herpetology Notes 6: 39–43.

Smith MA (1935) The Fauna of British India, Including Ceylon and Burma – Reptilia and Amphibia (Vol. II. Sauria). Taylor and Francis, London, 440 pp.

Snyder J, Snyder L, Bauer AM (2010) Ecological observations on the Gargoyle Gecko, *Rhacodactylus auriculatus* (Bavay, 1869), in southern New Caledonia. Salamandra (Frankfurt) 46: 37–47.

Soares de Oliveira BH, Mendonca de Queiroz RNM, Mesquita DO (2015) Communal nests and hatchling size of *Coleodactylus meridionalis* (Squamata: Sphaerodactylidae) in a Caatinga area, northeastern Brazil. Herpetology Notes 8: 125–128.

Sodhi SV, Ehrlich RP (2010) Conservation Biology for All. Oxford University Press, 369 pp. https://doi.org/10.1093/acprof:oso/9780199554232.001.0001

Sönmez B (2018) Relationship between metabolic heating and nesting parameters in Green Turtles (*Chelonia mydas*, L. 1758) on Samandag beach, Turkey. Zoological Science 35(3): 243–248. https://doi.org/10.2108/zs180003

Somaweera R (2009) Reproductive ecology of the Kandyan Day Gecko, *Cnemaspis kandiana*, in Gannoruwa forest reserve. Journal of the National Science Foundation of Sri Lanka 37(1): 13–22. https://doi.org/10.4038/jnsfsr.v37i1.453

Srinivasulu C, Srinivasulu B (2013a) *Cnemaspis indraneildasii*. The IUCN Red List of Threatened Species: e. T172592A1348091.

Srinivasulu C, Srinivasulu B (2013b) *Cnemaspis mysoriensis*. The IUCN Red List of Threatened Species: e. T194096A2298136.

Srinivasulu C, Kumar GC, Srinivasulu B (2015) A new species of *Cnemaspis* (Sauria: Gekkonidae) from Northern Karnataka, India. Zootaxa 3947(1): 085–098. https://doi.org/10.11646/zootaxa.3947.1.5

Uetz P, Hošek J (2017) The Reptile Database. http://reptile-database.reptarium.cz/ search?search=Cnemaspis&submit=Search [accessed 15 July 2017]

van Schingen M, Pham CT, An HT, Nguyen TQ, Bernardes M, Bonkowski M, Ziegler T (2015) First ecological assessment of the endangered crocodile lizard *Shinisaurus crocodilurus* Ahl, 1930 in Vietnam: Microhabitat characterization and habitat selection. Herpetological Conservation and Biology 10: 948–958.

Vidanapathirana RD, Gehan Rajeev MD, Wickramasinghe N, Fernando SS, Wickramasinghe LJM (2014) *Cnemaspis rammalensis* sp. nov., Sri Lanka's largest day-gecko (Sauria: Gekkonidae: *Cnemaspis*) from Rammalakanda Man and Biosphere Reserve in southern Sri Lanka. Zootaxa 3755(3): 273–286. https://doi.org/10.11646/zootaxa.3755.3.5

Vié JC, Hilton-Taylor C, Stuart SN (2009) Wildlife in a changing world – an analysis of the 2008 IUCN Red List of Threatened Species, 180 pp.

Vitt LJ (1986) Reproductive tactics of sympatric gekkonid lizards with a comment on the evolutionary and ecological consequences of invariant clutch size. Copeia 3(3): 773–786. https://doi.org/10.2307/1444960

Vrcibradic D, Eisfeld A (2016) Predation on a tropical house gecko, *Hemidactylus mabouia* by a juvenile colubrid snake, *Chironius bicarinatus,* in a Brazilian Atlantic Rainforest area. Cuadernos de Herpetología 30(2): 75–77.

Wickramasinghe LJM, Munindradasa DAI (2007) Review of the genus Cnemaspis Strauch, 1887 (Sauria: Gekkonidae) in Sri Lanka with the description of five new species. Zootaxa 1490: 1–63.

Werner YL (2002) Observations on the ecology of the arrhythmic equatorial gecko *Cnemaspis kendallii* in Singapore (Sauria: Gekkoninae). The Raffles Bulletin of Zoology 50(1): 185–196.

Whiles MR, Grubaugh JW (1993) Importance of coarse Woody Debris to southern forest Herpetofauna. Proceedings of the workshop on Coarse Woody Debris in Southern Forest: Effects on Biodiversity: 94–100.

Whitaker R, Captain A (2004) Snakes of India: The Field Guide. Draco Books, India, 481 pp.

Ziegler T, Rauhaus A, Nguyen VK, Nguyen QT (2016) Building of a conservation breeding facility for the Psychedelic Rock Gecko (*Cnemaspis psychedelica*) in Southern Vietnam. Der Zoologische Garten 85(5): 224–239. https://doi.org/10.1016/j.zoolgart.2016.05.002